Cardiovascular System

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Syllabus of BNS [5 hours]

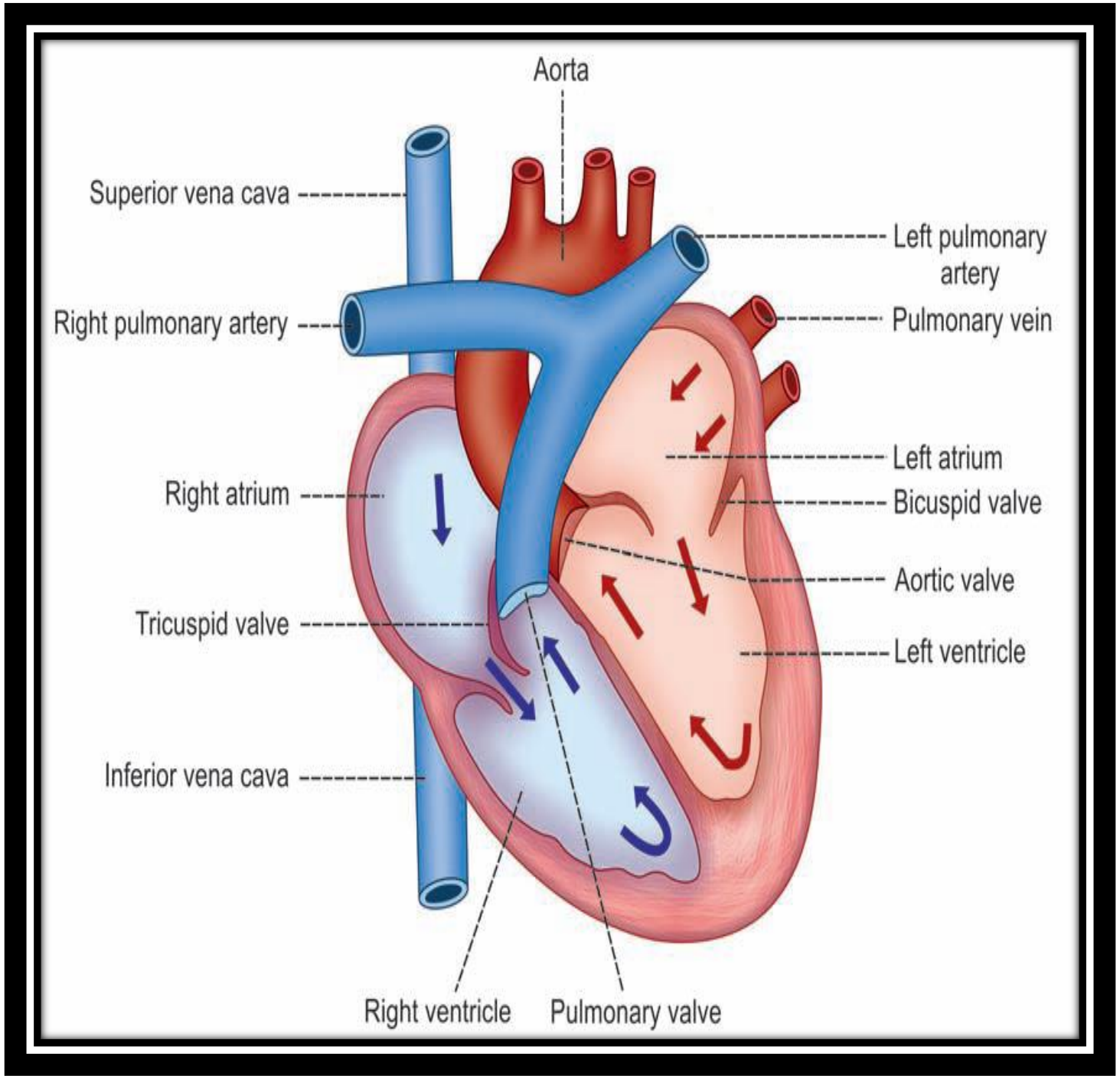
- General organization of Cardiovascular system [Overview & Components]
- Functional anatomy of Heart.
- Structure & properties of Cardiac muscle.
- Conducting system of Heart.
- Coronary circulation
- Cardiac cycle [systole & Diastole]
- Cardiac output [Definition, regulation]
- Arterial BP [Systolic BP, Diastolic BP, Mean Arterial BP, Pulse pressure, Short term & long term regulation]
- Heart rate [Heart Rate, Pulse rate, regulation]
- Pulse [definition, normal rate]
- Heart sounds [1^{st} & 2^{nd} heart sounds]
- Clinical aspects: [Tachycardia, Bradycardia, ECG, Shock, HTN, Angina, MI, CHF]

Syllabus of B.Sc. Nursing [6 hours]

- Control of blood flow [Vasodilation & Vasoconstriction]
- Blood supply for internal nutrition & cell nutrition
- Heart rate & factors affecting it
- Cardiac cycle
- Cardiac output
- BP [regulation, relationship between CO & BP]
- Pulse [factors affecting, relationship between Pulse rate & BP]

HEART

- Muscular organ that pumps blood throughout circulatory system.
- Situated in mediastinum (between two lungs).
- Four chambers (2 atria & 2 ventricles).
- Musculature of ventricles is thicker than that of atria.



- Right atrium
  - Thin walled & low pressure chamber.
  - It has got the pacemaker (Sinoatrial node, Atrioventricular node)
  - Receives venous (deoxygenated) blood via two **Superior vena cava** (from head, neck & upper limbs) & **Inferior vena cava** (from lower parts of body).
- Tricuspid Valve
  - Communicates Right atrium (thin wall) with right ventricle (thick wall).
  - Allows entry of venous blood from right atrium to right ventricle.
- Venous blood from Right ventricle → pulmonary artery → carries to lungs (for oxygenation).

- **Left atrium**
  - thin walled & low pressure chamber.
  - It receives oxygenated blood from lungs through pulmonary veins.
- Bicuspid valve: allows entry of blood from left atrium to left ventricle (thick walled).
- **Left ventricle** pumps arterial blood to different parts of body through **systemic aorta.**

SEPTA OF THE HEART

- Right & left atria are separated from one another by a fibrous septum called **interatrial septum (**membranous**).**
- Right & left ventricles are separated from one another by **interventricular septum (**muscular**).**

LAYERS OF WALL OF THE HEART

1. Outer pericardium
2. Middle myocardium
3. Inner endocardium.

- Pericardium is made up of two layers:
  - Outer parietal pericardium
  - Inner visceral pericardium.
- Space between two layers is called **pericardial cavity** or **pericardial space** (contains thin film of fluid).

- **Parietal Pericardium** (protective sac) for heart is made up two layers:
  - Outer fibrous layer (formed by thick fibrous connective tissue)
    - Protects heart from over stretching.
  - Inner serous layer (formed by mesothelium, & connective tissue)
    - Squamous epithelial cells of mesothelium secrete a small amount of fluid:
      - lines pericardial space.
      - prevents friction & allows free movement of heart.

- **Visceral pericardium** (**epicardium)** (formed by flattened epithelial cells), lines the surface of myocardium.

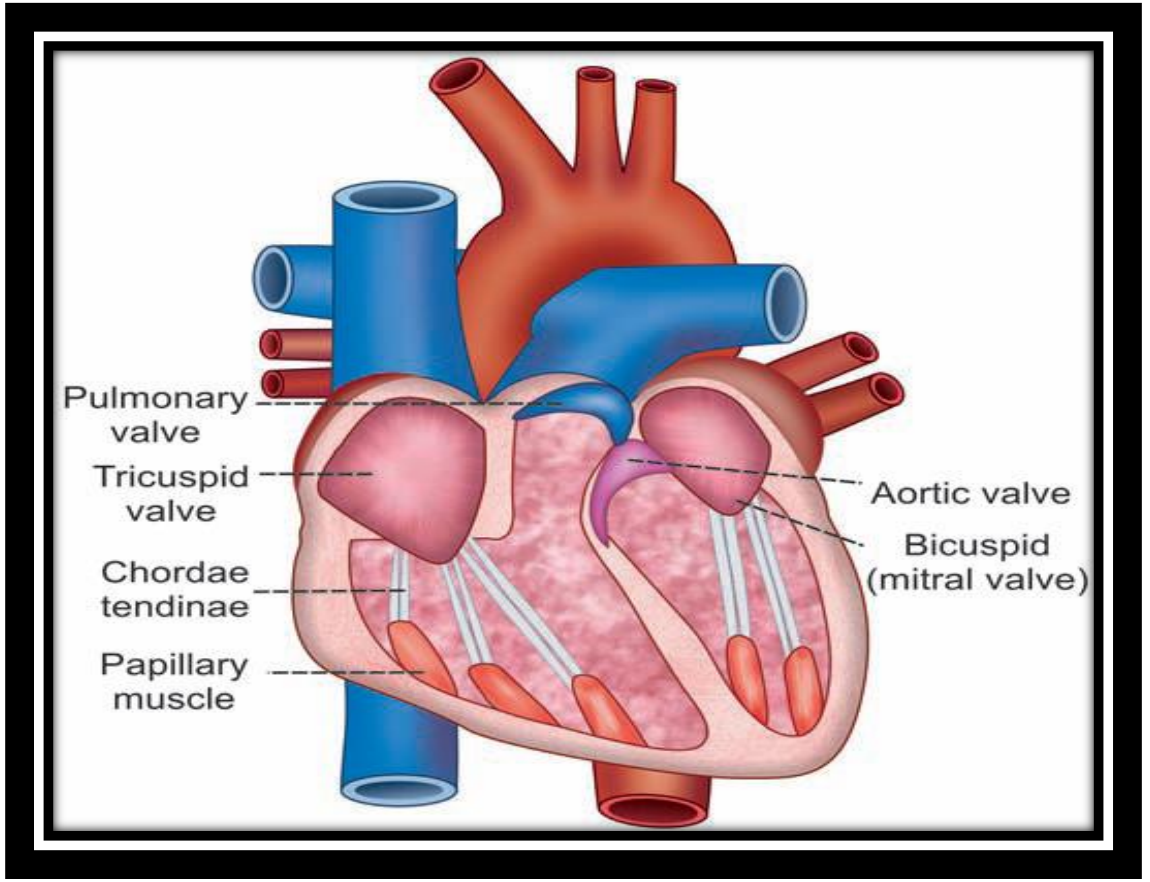
- **MYOCARDIUM** (forms the bulk of heart)
  - It is responsible for pumping action of heart.
  - Formed by cardiac muscle fibres (involuntary in nature).
  - Myocardium has three types of muscle fibres:
    1. Muscle fibres which form contractile unit of heart
    2. Muscle fibres which form pacemaker
    3. Muscle fibres which form conductive system.

- **ENDOCARDIUM**
- It is formed by a single layer of endothelial cells, lining inner surface of heart.
- Endocardium continues as endothelium of the blood vessels.

Four valves of Heart

- **<u>Atrio-ventricular Valves</u>**

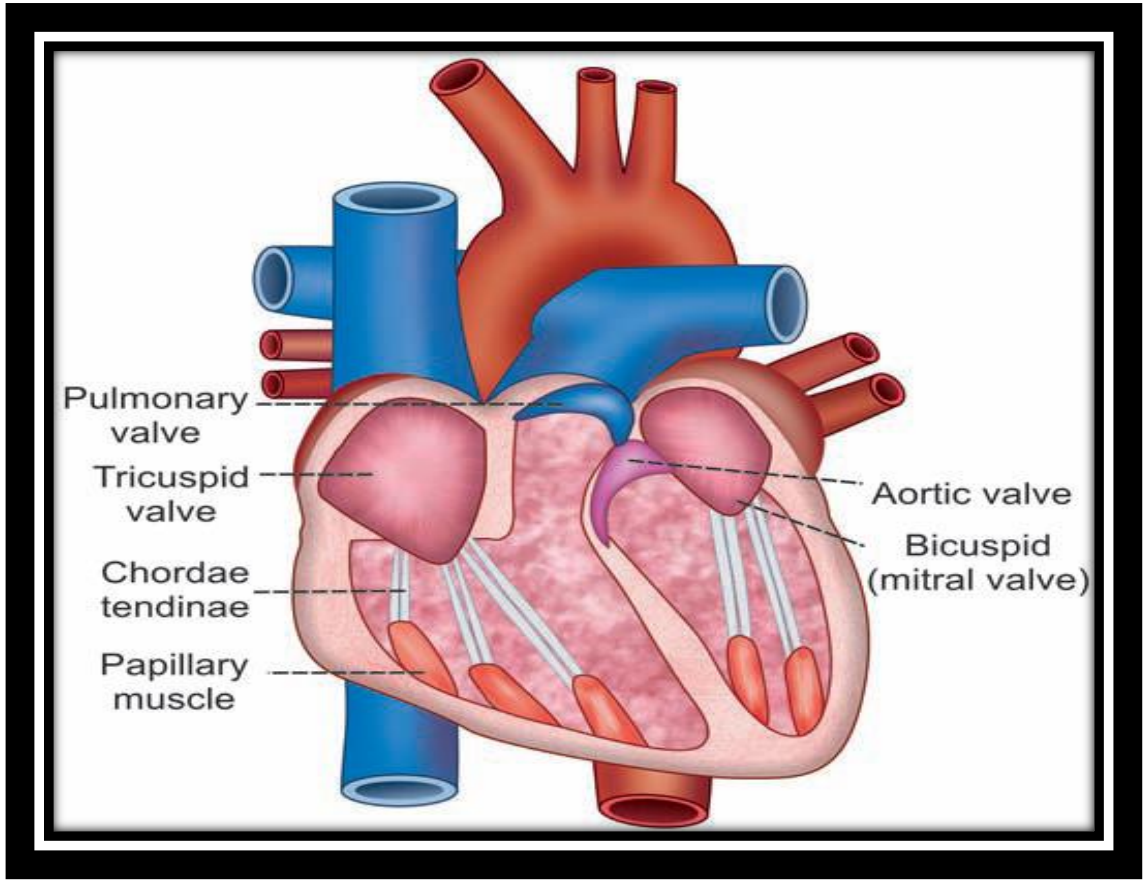
- Left AV-valve (**mitral** or **bicuspid),** formed by two valvular **cusps**
- Right AV-valve (**tricuspid valve),** formed by three cusps.
- **Function**: open only towards ventricles, prevent backflow of blood into atria.



Four valves of Heart

Semilunar Valves (half moon shape)

- **Aortic Valve (**at openings of systemic aorta)
- **Pulmonary valve (**at openings of pulmonary artery)
- Function: open only towards aorta & pulmonary artery, prevent backflow of blood into ventricles.

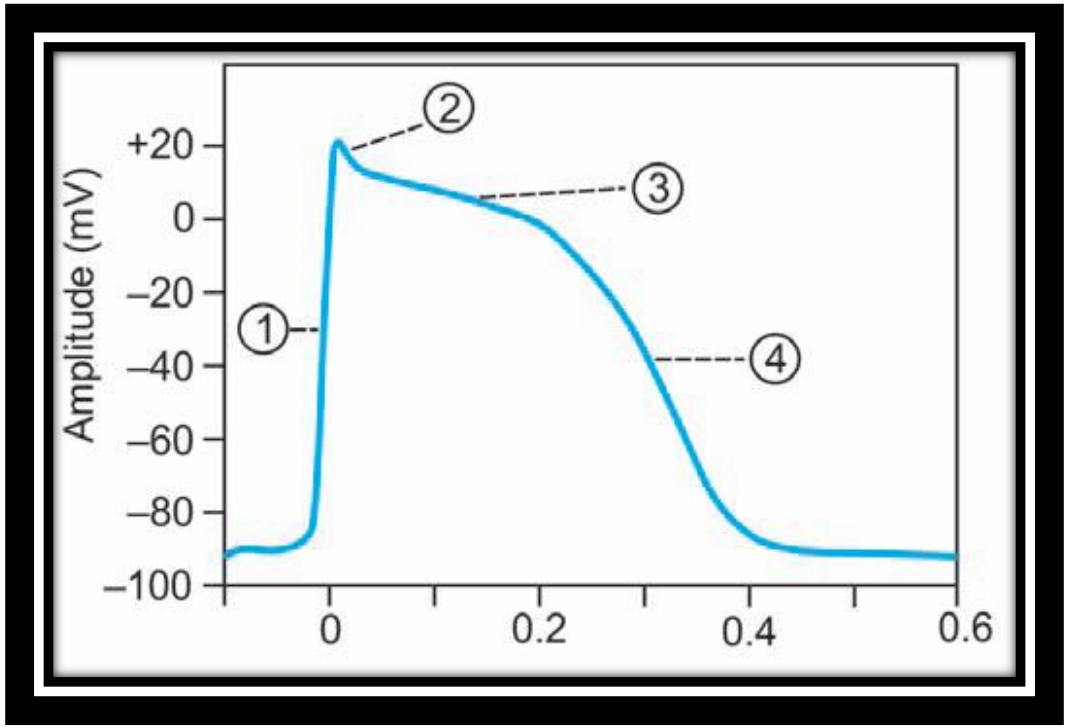


Action Potential of a single muscle fibre

1. Rapid depolarization [2 msec] [+20 mV]
   - Due to Na+ influx & Ca++ influx

2. Initial repolarization [2 m sec]
   - Due to K+ efflux & decreased Na+ influx

3. Plateau [*Final Depolarization]*
   - 200 msec in atrial muscle fiber & 300 msec in ventricular muscle fiber
   - Increased K^+ efflux & slow Ca^{++} influx.
   - Long plateau → Contraction time is longer in cardiac muscle.



4. Final Repolarization [50 to 80 msec]
   - Slow process
   - Inactivation of Ca++ channel
   - Opening of K+ channel [K+ efflux]

5. RMP
   - Re-established by Na^+-K^+-ATPase

Properties of Cardiac Muscle

- **EXCITABILITY**
- **RHYTHMICITY**
- **CONDUCTIVITY**
- **CONTRACTILITY**

EXCITABILITY

- It is the ability to respond to a stimulus (generation of action potential).

	RMP
Single cardiac muscle fiber	– 85 to – 95 mV
SA node	– 55 to – 60 mV
Purkinje fibers	– 90 to – 100 mV

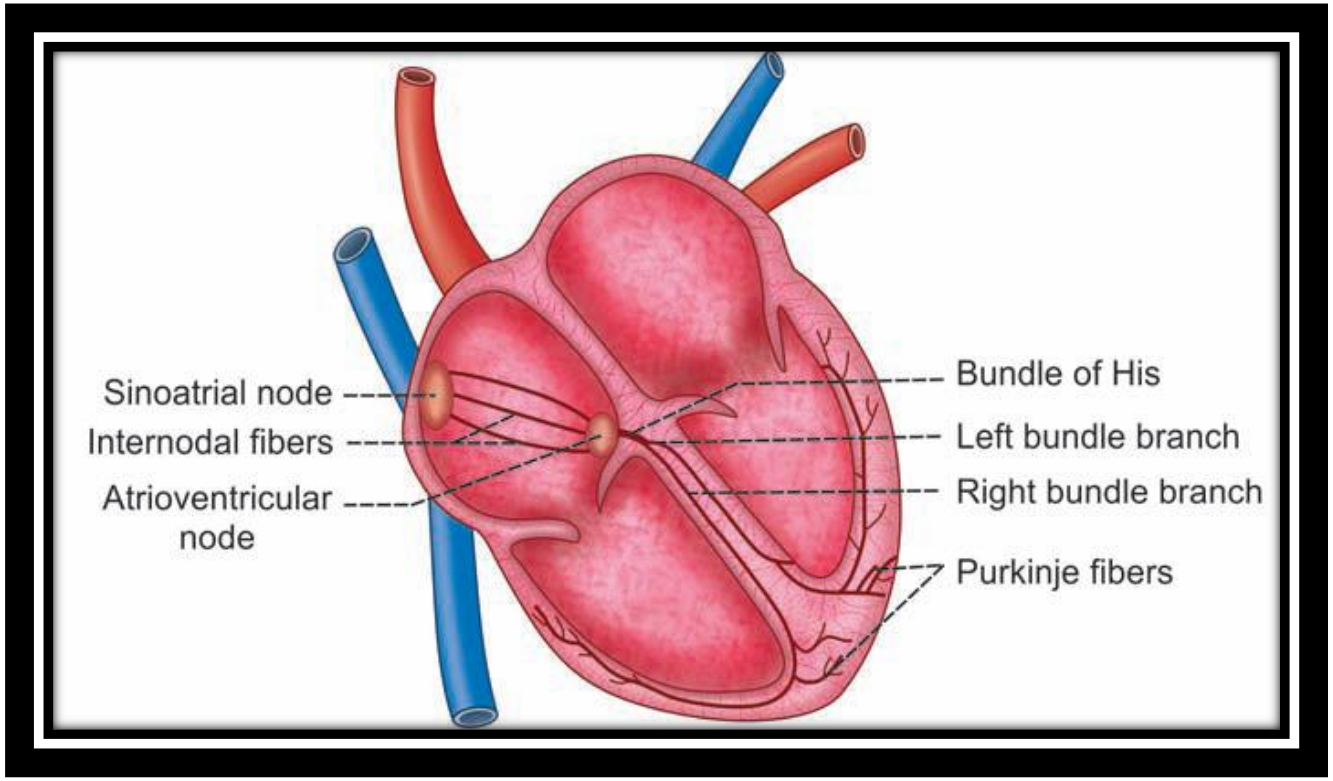
Rhythmicity

- Ability to produce its own impulses regularly [autorhythmicity, self excitation] due to presence of pacemaker tissue in heart.
- Pacemaker (made up of “P” cells) produces impulses for heart beat.
- In mammalian heart, the pacemaker is sinoatrial node (SA node).

Rate of production of impulse (rhythmicity)	
SA node	70-80/min
AV node	40-60/min
Atrial muscle	40-60/min
Purkinje fibre	35-40/min
Ventricular muscle	20-40/min

Conductivity

- Conducting system of heart is formed by Junctional tissue (modified cardiac muscle fibre).
- Junctional tissue in our heart are SA node, AV node, Right & left bundle branches, Bundle of His, Purkinje fibres, Internodal tracts.



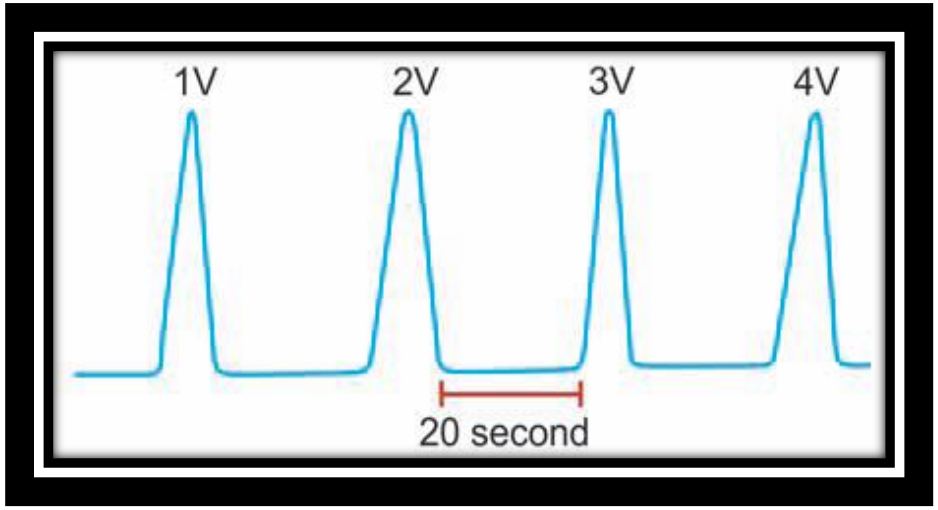
VELOCITY OF IMPULSES AT DIFFERENT PARTS OF CONDUCTIVE SYSTEM	
Atrial muscle fibers	**0.3 m/s**
Internodal fibers	**1 m/s**
AV node	**0.05 m/s**
Bundle of His	**0.12 m/s**
Purkinje fibers	**4.0 m/s**
Ventricular muscle fibers	**0.5 m/s**

Contractility

- Ability to shorten in length (contraction) after receiving a stimulus.
  [All or None law, Staircase phenomenon, Refractory period]

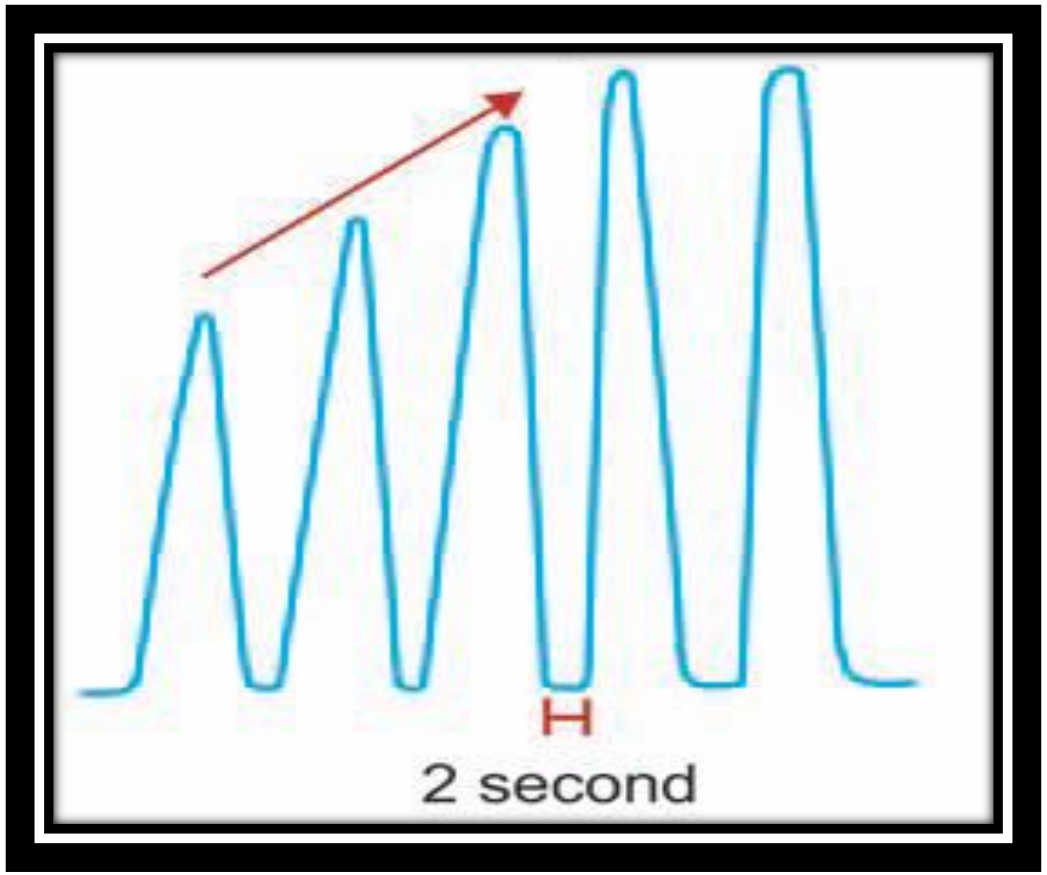
ALL-OR-NONE LAW

- **When a stimulus of any strength is applied;**
  - **Whole cardiac muscle gives maximum response or**
  - **It doesn't give any response at all.**
- **All or none law is applicable to whole cardiac muscle due to its syncytial arrangement.**



Staircase Phenomenon

- When cardiac muscle is stimulated at a short interval of 2 sec, with stimulus of same strength, force of contraction increases gradually for the first few contractions (due to beneficial effect) and then it remains same.



Refractory period

- It is the period in which the muscle is non responsive to re-stimulation.
- Cardiac muscle has a **long refractory period** compared to skeletal muscle.

Advantage of Long Refractory Period

- Summation of contractions does not occur
- Fatigue does not occur
- Tetanus does not occur.

Refractory period

Absolute Refractory Period [0.27 sec]

- Muscle doesn't show any response at all, whatever may be the strength of stimulus.
- Due to ongoing depolarization, 2nd depolarization isn't possible.
- Extends throughout the contraction period of cardiac muscle

Relative Refractory Period [0.26 sec]

- Muscle show response if strength of stimulus is maximum.
- Muscle is in repolarizing state, thus show response with maximal stimulus.

Frank Starling Law

- Within physiological limit, force of contraction of ventricular muscle fibre is directly proportional to its initial length.
- Significance: It explains that blood ejected by each ventricles per heart beat is same.

If Rt. Ventricle output > Lt. ventricle output

↓

Blood accumulate in Lt. ventricle

↓

Increase in initial length

↓

Increase output by Lt. ventricle

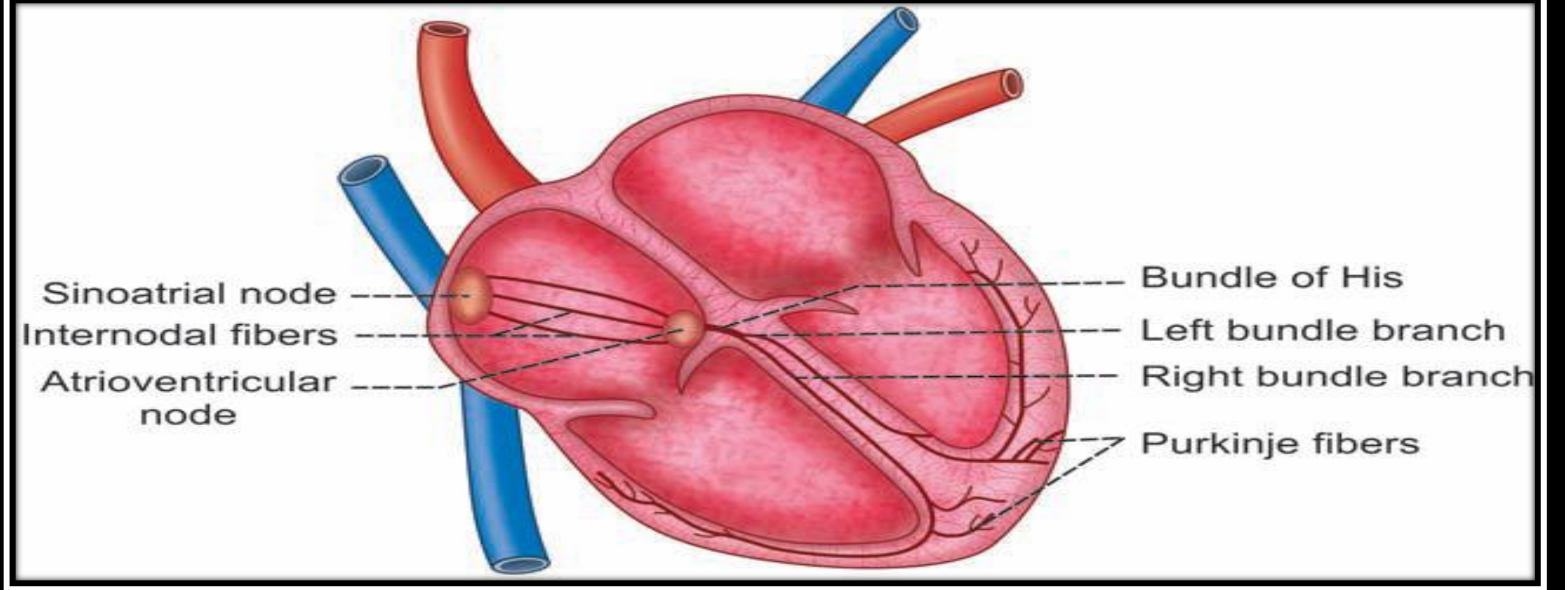
[Rt. Ventricle output = Lt. ventricle output]

Junctional tissue of Heart [Conductive System of Heart]

- Includes:
  - Sino-Atrial node
  - Internodal tracts [Anterior, Middle, Posterior]
  - Atrio-ventricular node
  - Bundle of His (AV bundle)
  - Right & Left bundle branches
  - Purkinje fibres

Junctional tissue of Heart [Conductive System of Heart]

- Modified myocardial cells, concerned with initiation & conduction of impulse.



Sino-Atrial node

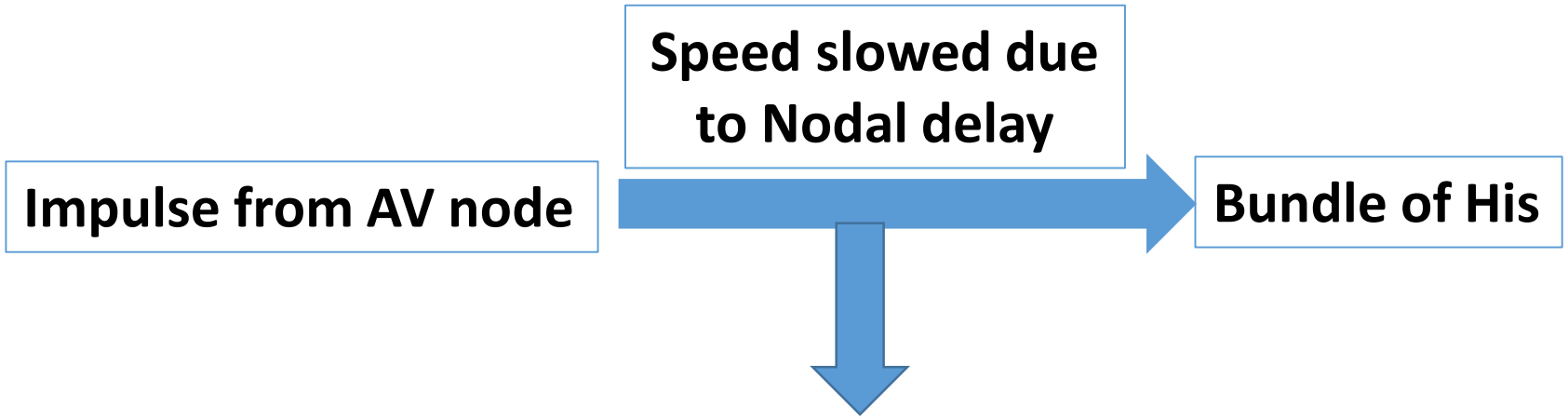
- Situated at junction between Rt. Atrium & Superior venacava.
- Composed of:
  - "P" cells: produce impulse
  - Adjacent cells: carry impulse generated by "P-cells"
- **SA node called as Pacemaker of Heart**.
  - Heart beats according to rhythm created by SA node.
  - Impulse generated by SA node is faster than other pacemakers tissue of Heart.
- Impulse from SA node simultaneously travels towards:
  - Atrial musculature in all direction [slowly] [Rt. Atrium 1st]
  - AV node via atrial intermodal tract [higher speed].

Internodal tract (Inter Nodal Atrial pathway)

- Conduct impulse from SA node to AV node.
- Arranged in 3 bundles:-
  - Anterior intermodal tract of Bachman.
  - Middle intermodal tract of Wenckebach.
  - Posterior intermodal tract of Thorel.

Atrio-ventricular node

- Situated in right posterior portion of interatrial septum.
- Bundle of His starts from here.
- **“P-cells” in AV node (40 -60/min) generate impulse with slower rate than SA-node (70-80 /min).**



- **Nodal delay occurs due to low RMP.**
- **Advantage:**
  - **Allows completion of atrial contraction before ventricular contraction.**
  - **Helps in proper filling of ventricles**

Bundle of His & its Branches

- **Thick bundle**
- **Originate from AV node.**
- **Conduct impulse to ventricles.**

Left branch

Supply Left ventricle & IV septum

Right branch

Supply Right ventricle

Purkinje Fibre

- From each branch of bundle of His, many **Purkinje fibers** arise and spread all over the ventricular myocardium.
- Transfer impulse to working myocardial cells.

Cardiac Cycle

- It is defined as complex series of events occurring between beginning of one heart beat to the beginning of next heart beat.
- Normal duration: 0.8 sec [at normal heart rate (75/min)]

Heart Rate	Cardiac cycle	Systole	Diastole
120/min	0.5 sec	0.23 sec	0.27 sec
75/min	0.8 sec	0.3 sec	0.5 sec
60/min	1.0	0.33 sec	0.67 sec

Cardiac Cycle

Events in the Cardiac Cycle:

- Atrial Systole
- Ventricular Systole
  - Isometric contraction
  - Ejection period
- Ventricular Disatole
  - Protodiastole
  - Isometric relaxation
  - Filling of ventricles
- Atrial Diastole

Atrial Systole [Atrial contraction phase] (0.1 sec)

Atrial contraction [produce 4th Heart Sound]

Increase in atrial pressure
[Rt. atrium: by 4-6 mm Hg]
[Lt. atrium: by 7-8 mm Hg

25% of blood flows into ventricles

- Blood flows into ventricles:
  - 75% without Atrial contraction
  - 25% with Atrial contraction

Ventricular Systole

Isometric ventricular contraction [0.05 sec]

Increase in ventricular pressure

↓

Closure of AV valve [1st Heart Sound]

↓

Isometric contraction of ventricles

↓

Increase in ventricular pressure

[Rt. Ventricle: to 8 mm Hg]

[Lt. ventricle: to 80 mm Hg]

↓

Opening of Semilunar valve

↓

Ejection of blood from ventricles

Ejection period

- Rapid ejection phase [0.11 sec]
  - Opening of Semilunar valve → 2/3rd of blood is rapidly ejected from both ventricles.
- Slow ejection phase [0.14 sec]
  - Rapid ejection → decrease in ventricular pressure → 1/3rd of blood is slowly ejected from both ventricles.

Ventricular Disatole

Protodiastole [0.04 sec]

Ejection of blood

↓

Pressure in Pulmonary artery & Aorta is more than pressure in ventricles

↓

Semilunar valve closed [2nd Heart sound]

Protodiastole indicate end of systole & beginning of diastole.

Isometric relaxation 0.06 sec]

Closure of all valves

↓

Both ventricles relaxes as closed cavity

↓

Decrease in intraventricular pressure

↓

Opening of AV valve

↓

Filling of ventricles

Filling of ventricles

- Rapid filling phase [0.11 sec]
  - Opening of AV valve → 70% of blood rushes into ventricles [3rd Heart sound]
- Slow filling phase [0.19 sec]
  - Decrease in intra atrial pressure → slow filling occurs.

Atrial Diastole [0.7 sec]

- Atrial diastole (relaxation) & ventricular systole starts simultaneously.
- Long atrial diastole is necessary for atrial filling.
- Superior & inferior venacava → deoxygenated blood → Right atrium.
- pulmonary veins → oxygenated blood → Left atrium.

- In clinical practice, the term ‘systole’ refers to ventricular systole & ‘diastole’ refers to ventricular diastole.

Ventricular systole [0.27 sec]	
Isometric contraction	0.05 sec
Ejection period	0.22 sec

Ventricular diastole [0.53 sec]	
Protodiastole	0.04 sec
Isometric contraction	0.08 sec
Rapid filling	0.11 sec
Slow filling	0.19 sec
Last rapid filling (Atrial systole)	0.11 sec

Heart Sounds

- Sounds produced by mechanical activities of heart during each cardiac cycle.

1st Heart Sound

- During isometric contraction & early part of ejection → closure of AV valve → 1st Heart sound produced [LUBB].
- Duration: 0.10 to 0.17 sec
- Frequency: 25-45 cycle/sec.

Applied Physiology	
Stenosis of AV valve, Atrial septal defect	**splitting of 1st Heart sound**
Hypotension, Heart failure, MI	**intensity of 1st Heart sound decreases**
Mitral stenosis	**loud 1st heart sound**
Complete heart block	**1st Heart sound heard intermittently (Canon sound)**

2nd Heart Sound

- During protodiastolic period→ closure of Semilunar valve → 2nd Heart sound produced [DUBB].
- Duration: 0.14 sec
- Frequency: 50 cycle/sec.

Applied Physiology	
Right bundle branch block, Right ventricular hypertrophy	**splitting of 2nd Heart sound**
Leftt bundle branch block, Leftt ventricular hypertrophy	**Reverse splitting of 2nd Heart sound [due to delay in emptying of left ventricle)**

3rd Heart Sound

- During rapid filling phase → vibration in ventricular wall → 3rd Heart sound produced.
- Duration: 0.07-0.10 sec
- Frequency: 1-6 cycle/sec.
- Can be heard only by using microphone.

Applied Physiology	
Cardiac failure **Aortic regurgitation**	**Can be heard by sthethoscope**

4th Heart Sound

- Audible only in pathological condition.

Atrial systole

↓

Vibration in atrial muscle

Ventricular distention

↓

Vibration in ventricular myocardium

4th Heart sound produced

Duration: 0.02-0.04 sec

Frequency: 1-4 cycle/sec.

Applied Physiology	
Ventricular Hypertrophy Aortic Stenosis	Can be heard by Stethoscope